Tropical Cyclone Outflow Patterns and Intensity Change

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Introduction/Background

Based on Masters thesis results of Spratt (1990)

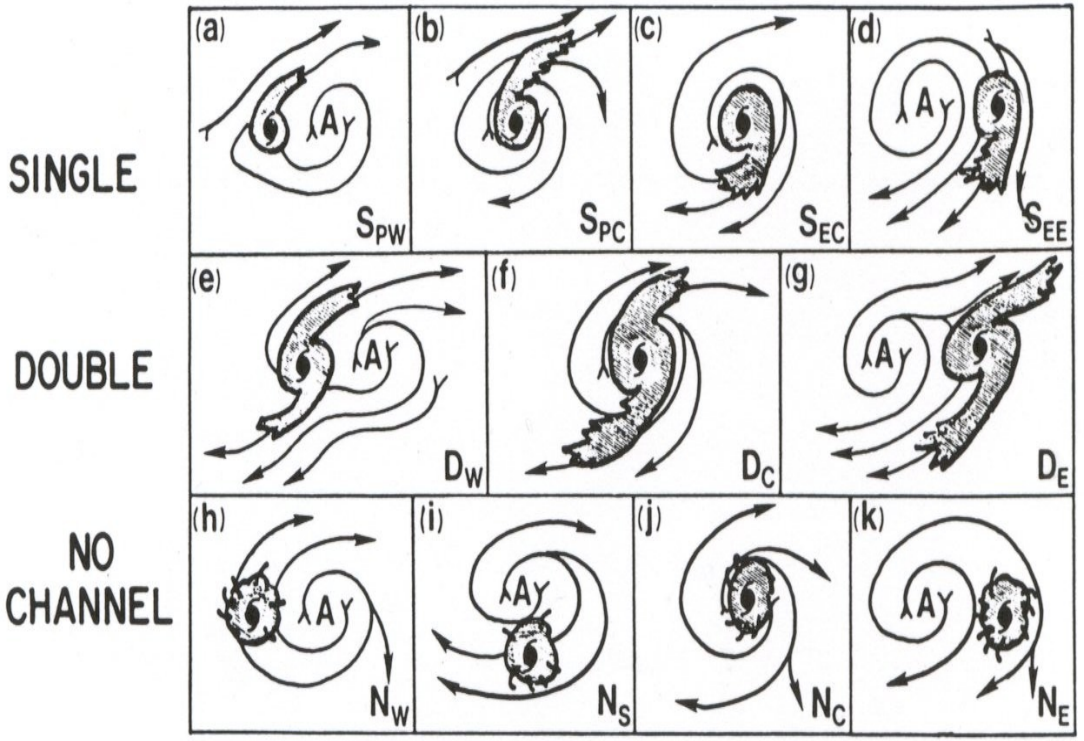
- An observational study of western north Pacific tropical cyclones:
  - 112 storms from 1979 to 1985 (0 - 40N, 110-150E)
  - JTWC best track data (from ATCR's)
  - GMS satellite mosaics of western Pacific
  - NMC 250 mb Streamline Analysis

- **Chen & Gray (1985):** identified several environmental patterns most conducive to TC intensity change.
- Builds upon Chen & Gray's work by further relating upper level outflow patterns to TC intensification.
- Emphasis on improved understanding of rapid intensification associated with the TUTT.

Upper Level Outflow Patterns: Chen and Gray (1985)

- Cloud pattern types are classified by the cirrus outflow orientation relative to the TC center:

  Single Polar (SP)
  Single Equatorial (SE)
  Double Channel (D)
  Non-Channel (N)



- Further categorized by the location of the TC center relative to its associated upper level anticyclone.

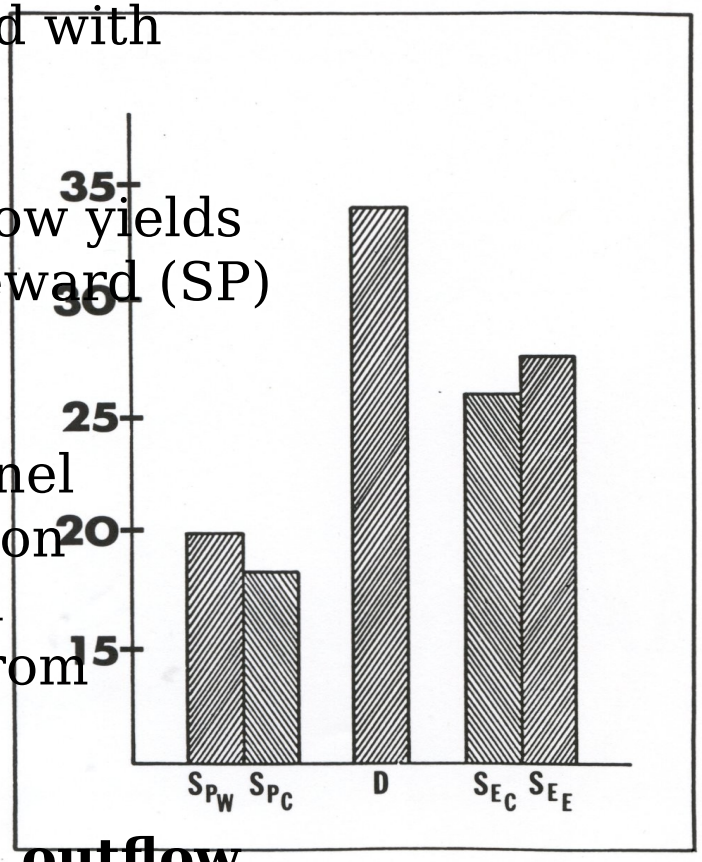
Outflow Patterns and associated Intensity Change: Chen and Gray (1985)

- Double channel outflow is associated with the fastest intensification rates.

- On average, equatorward (SE) outflow yields greater intensification rates than poleward (SP) outflow.

- No statistics are given for non-channel cases. The observed rapid intensification of some TCs were not accounted for in their study (e.g. Supertyphoon Vera: from 25 to 140 kts in 48 hours)

Conclusion: Only distinct, vigorous outflow results in large rates of intensification.



Average wind speed increase (kno
per 24 hours.

Cloud Pattern Type Additions/Changes Spratt (1990)

Eastward Cloud Pattern (E*)

- This fifth category was added due to the unique cloud patterns which developed during TC/TUTT interactions.

- Clouds generally emanate far eastward and correspond to strong, narrow bands of westerly flow extending south of TUTT systems located to the north or northeast of TC centers.

- Sometimes accompanied by equatorward outflow, indicated by long cirrus plumes extending southwestward.

- Thus, Chen and Gray (1985) erroneously included these systems in their single-channel equatorward category (SP).

Uniform cloud pattern (U)

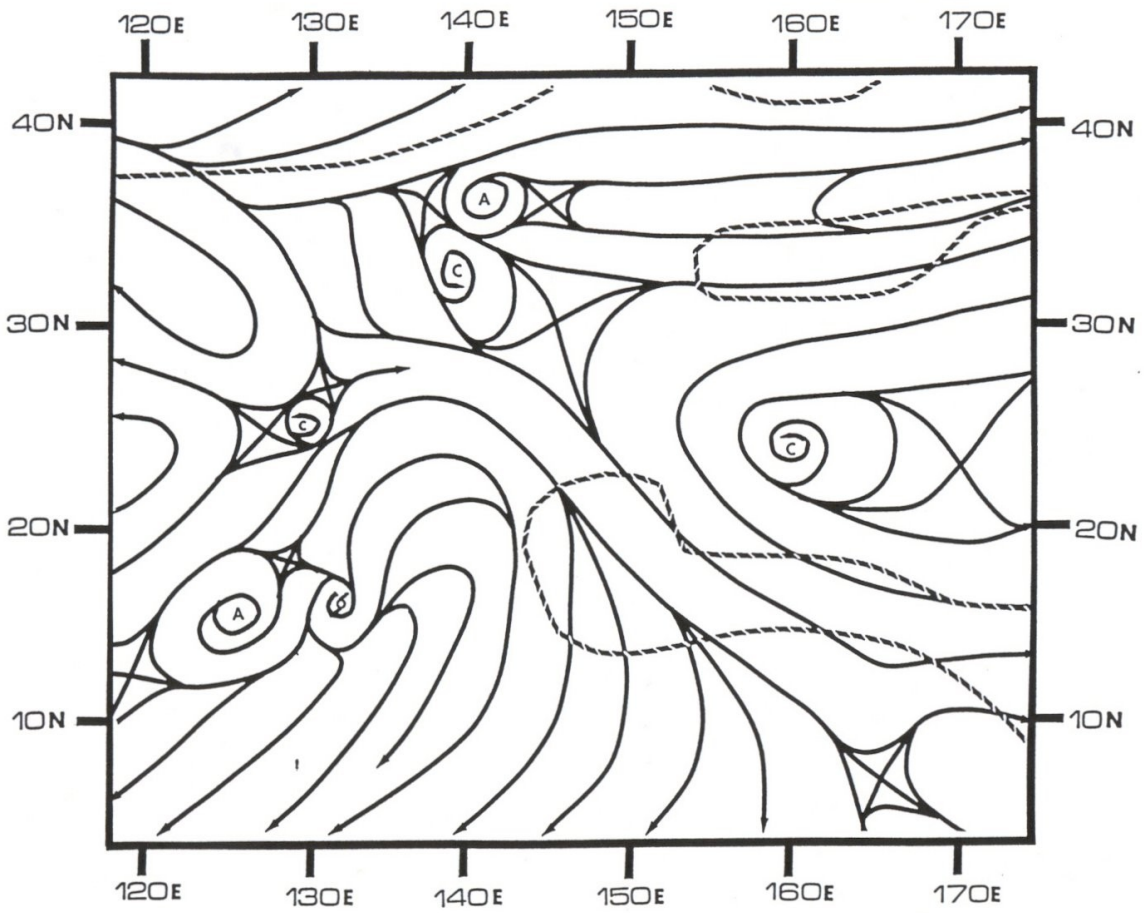
- Replaces the Non-Channel category
- Characterized by strong, symmetric upper level divergence (CDO patterns in satellite imagery)

Supertyphoon Abby (1983)
Eastward Outflow Pattern

- Explosively intensified from 75 to 135 knots in 24 hours while displaying this upper level flow pattern.

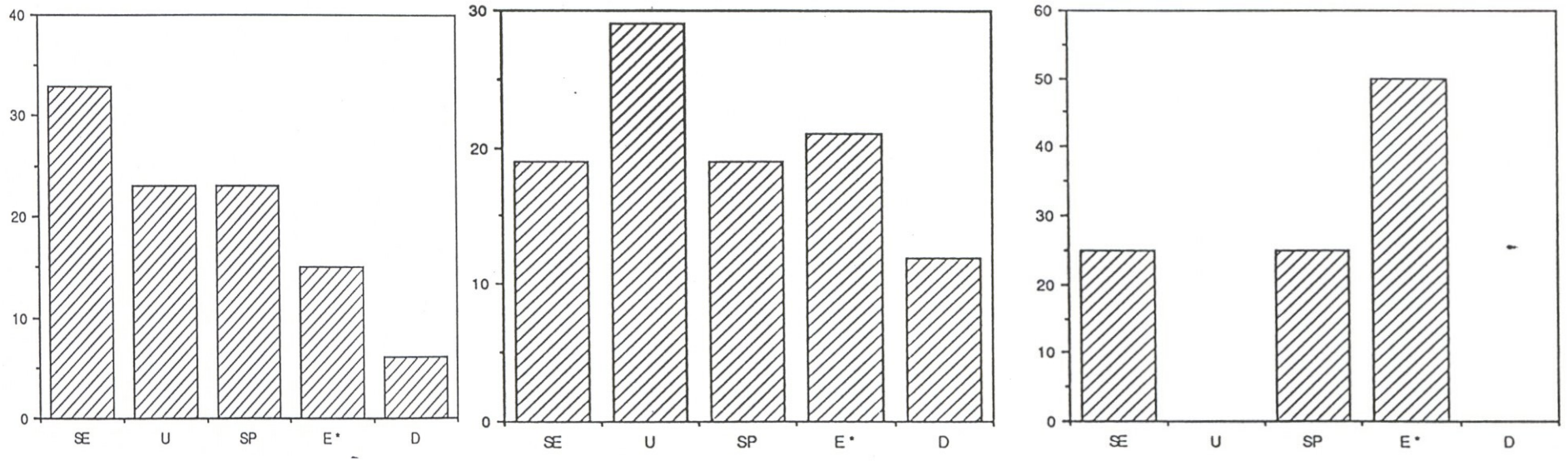
- Note the equatorward outflow in addition to the flow extending far eastward, south of the TUTT. This is common for the E* pattern.

- Similar patterns



08-Aug-83 (12 UTC) 250 mb streamline analysis (sol
Isotachs (dashed lines) are contoured at 40 knot inte

Relative Frequency of TC Cloud Pattern displayed during Intensification

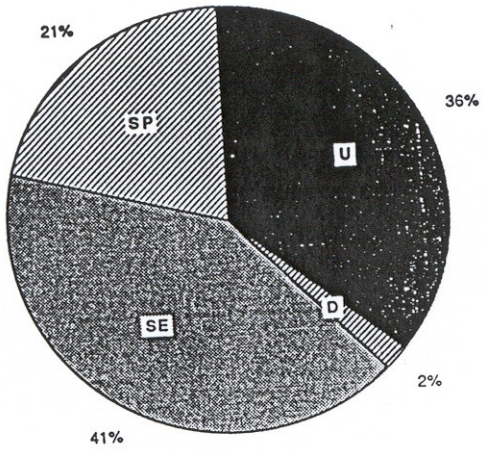


- <u>All Systems</u> - Equatorward Outflow most prevalent.

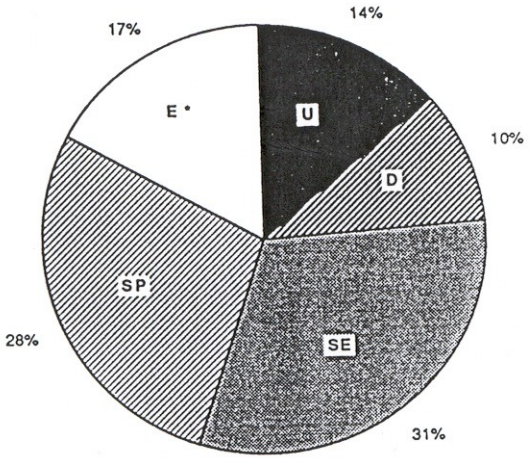
- <u>Rapid Intensification</u> (at least 15 mb/12 hr drop in central pressure)
  Uniform pattern (U) most frequent. E* pattern becomes relatively more frequent

- <u>Explosive Intensification</u> (at least 30 mb/12 hr drop in central pressure)

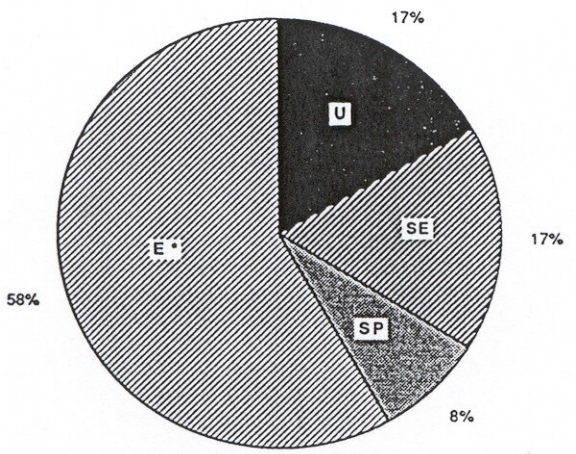
Relative Frequency of Cloud Pattern displayed during Intensification



TROPICAL STORMS (42)



TYPHOONS (58)



SUPERTYPHOONS (12)

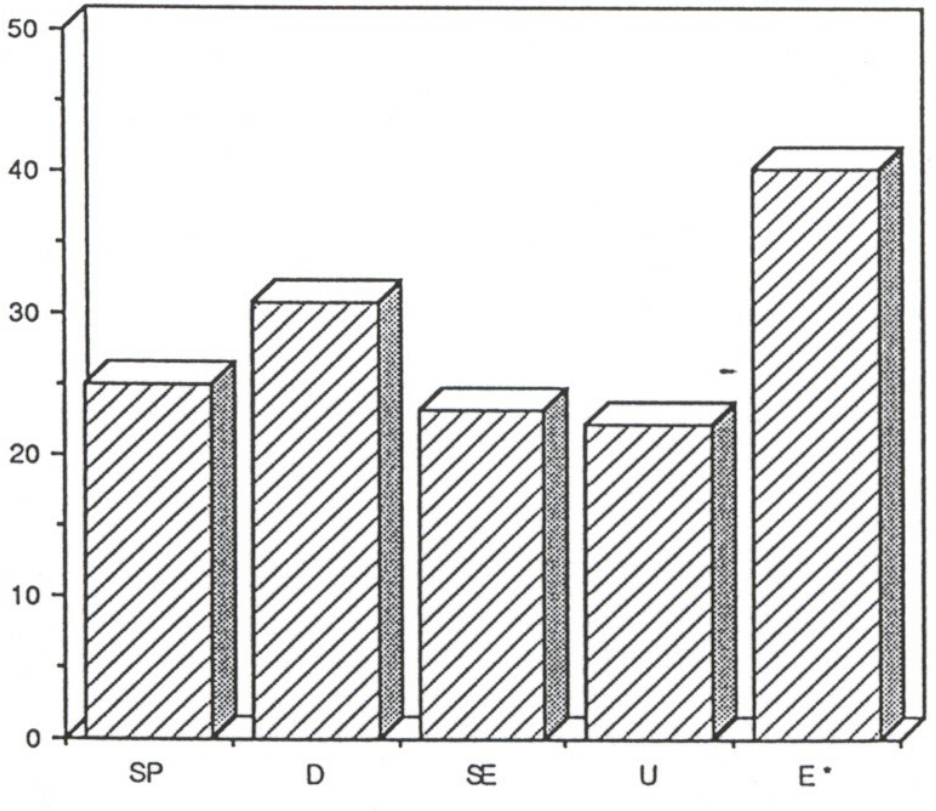
- Grouped by the ultimate intensity obtained by tropical cyclone
- The greater intensity that a TC attains, the Eastward (E*) patt becomes more frequently observed during intensification.
- Double Channel outflow patterns were never observed for sup

Average Intensification Rates for Cloud Pattern Types

- On average, TCs displaying the E* cloud pattern intensified at a greater rate than TCs exhibiting the other four cloud patterns (SP,SE,D,U).

- Two-sample t-tests reveal a significant difference at the 95% confidence level between E* and each of the other patterns.

- No significant difference was found among the remaining cloud patterns.



Average maximum wind increases associa
with individual cloud patterns (knots per

Summary of TC/TUTT Interactions: Eastward Cloud Patterns (E*)

- Eastward oriented cloud patterns coincide with the most rapid intensification.

- Most prevalent in a compact region northwest of Guam, where supertyphoons typically reach maximum intensity.

- East/West oriented TUTT systems located far to the north or northeast of this region allows TC outflow to link-up with this flow and intensify rapidly. *Note: Upper cells at close proximity to TC outflow did not significantly affect intensification for any storms in this study.*

Summary of Uniform Cloud Pattern/Intensification Relationship

- Typically occurs in low latitudes equatorward of the SER within monsoon trough.

- Characterized by a large radius of unrestricted, omni-directional, uniform outflow.

- Continuation over a significant time period often coincides with periods of enhanced intensification.

- Lack of distinct single or multi-channel outflow observed during rapid intensification contradicts conventional outflow theory.

Summary of Remaining Cloud Pattern/Intensification Relationships

Poleward Outflow (SP)

- Results from interaction with mid-latitude troughs, thus occurs at h
- Characterized by narrow, vigorous outflow to the westerlies.
- Some individual cases intensified rapidly, composites indicate other
- Effects of lower SSTs and wind shear in higher latitudes may count
  effects of outflow channels thus preventing or slowing intensificatio

Double Channel (D)

- Similar to SP pattern, but occurs at a slightly lower latitude, on ave
- Never observed to explosively intensify or reach supertyphoon inte
  to Chen and Gray's (1985) findings.

Equatorward (SE)

- Unique in that satellite imagery (NE flow) often contradicted the 25
  analysis (Easterly flow), which had no evidence of significant outflo

References

Chen, L. and W. M. Gray, 1985: Global view of the upper-level outfl associated with tropical cyclone intensity change during FGGE. D Sci. Paper No. 392, Colo. State Univ., Ft. Collins, CO, 126 pp.

Spratt, S., 1990: Tropical Cyclone Cloud Patterns: Climatology and intensity change. Masters Thesis, University of Hawaii, Honolulu, H